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FOCUS ON: TROPICAL DISEASES

# Severe acute respiratory syndrome (SARS) in intensive care units (ICUs): limiting the risk to healthcare workers

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## KEYWORDS

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Intensive care;  
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**Summary** The global epidemic of severe acute respiratory syndrome (SARS) during the first half of 2003 resulted in over 8000 cases with more than 800 deaths. Many of those who eventually died, did so in the critical (intensive) care units of various hospitals around the world, and many secondary cases of SARS arose in healthcare workers looking after such patients in these units. Research on SARS coronavirus (SARS CoV) demonstrated that this virus belongs to the same family of viruses, the *Coronaviridae* that causes the common cold, with some important differences. Properties of this virus have been discovered which can be used to develop important infection control policies within hospitals to limit the number of secondary cases. These properties include environmental survival, transmissibility, viral load in various organs and fluids and periods of symptomatic illness during which infectivity is greatest. Various barrier methods were used throughout the epidemic to protect healthcare workers from SARS, with varying degrees of success. Treatment of SARS patients has mainly involved steroid therapy, with or without ribavirin, but there is no consensus on the best treatment protocol, as yet. This review focuses on the implications of SARS for healthcare workers and patients on critical care units.

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## Introduction

Since its emergence from Guangdong province in China, severe acute respiratory syndrome (SARS) has been unique on several fronts. Firstly, the

disease is caused by a new member of the family *Coronaviridae*, with distinctive properties, setting it apart from the two other coronaviruses that are already known to cause the common cold in human beings.<sup>1</sup> Secondly, during its early emergence, it infected many healthcare workers (HCWs), including the index case from Guangdong, who transmitted the infection to individuals coming from different parts of the world.<sup>2–8</sup> Thirdly, it is the first

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global epidemic of a new emerging infection, which has been managed at an international level using the latest technology available as is described in the following: (a) the internet for rapid, 24h communication across all affected countries and time zones to exchange clinical and technical information;<sup>9–11</sup> (b) modern virological methods including both traditional whole animal/cell culture and electron microscopy,<sup>12,13</sup> and the newer molecular biological techniques that enabled the whole genetic sequence of the new virus to be obtained within 2 months of the onset of the global epidemic;<sup>14,15</sup> and (c) the rapid investigation of compounds for possible active agents to treat or immunize against the new illness.<sup>16–27</sup>

Because the SARS coronavirus (SARS-CoV) is known to be highly infectious, the impact on critical (intensive) care units (ICU) is of particular interest. It was in the ICUs that many of the patients with severe SARS died, and many of the initial wave of hospital-acquired or nosocomial transmissions of this new coronavirus virus occurred.<sup>28–34</sup>

## Origins

It is thought that SARS CoV is a zoonotic virus, and studies of Guangdong wildlife are ongoing at present to determine its origin.<sup>35,36</sup> The hypothesis is that due to the wide variety of exotic wild animals that are consumed as food delicacies in Guangdong province, in Southern China, the transmission of SARS CoV from animal to man occurred during capture, handling, preparation or consumption of these animals. This was supported by anecdotal reports that some patients, who had SARS in Guangdong Province in November and December of 2002, reported a history of occupational exposure to these exotic wild animals. Interestingly, two out of the recent four cases of SARS occurring early in 2004 had documented exposure to civet cats in a restaurant serving exotic wild animals and environmental samples taken from that restaurant were positive for SARS-CoV genome by reverse-transcriptase polymerase chain reaction (RT-PCR). This has led to the subsequent cull on these animals recently initiated by China.<sup>37,38</sup> A comparison can be drawn with other zoonotic viruses such as influenza, and Nipah virus, which have also recently emerged from the region of Southeast Asia.<sup>39,40</sup> Current animal candidates for the natural reservoir of SARS CoV include the Himalayan palm civet (*Paguma larvata*) and the racoon dog (*Nyctereutes procyo-*

*noides*).<sup>35,36</sup> There has also been a suggestion that the black rat (*Rattus rattus*) may also play a role as a vector.<sup>41</sup> The identification of the natural reservoir for the new SARS CoV has important practical public health implications because once it has been identified, it may be possible to limit the exposure and thus prevent further transmissions to susceptible people, thus minimizing the risk of another SARS epidemic. An interesting finding for SARS CoV strains isolated from the civet cat species was that the genome sequence was 29 nucleotide bases longer than the SARS CoV isolated from human SARS cases. It was suggested by the authors who reported this finding that this implied that it was therefore more likely that the virus had passed from civet cat to man, rather than vice versa.<sup>36</sup>

The recent and ongoing re-emergence of SARS in a few patients in Guangdong province in China in early 2004<sup>38,42,43</sup> shows that this virus may well become seasonal, and that clinical teams, globally, should remain alert for unsuspected SARS patients from such affected areas.

## Mortality

SARS has a mortality which is very age specific, being reported as: less than 5% for those aged under 25 years to over 50% for those aged over 65 years of age. Overall, ICU mortality has been reported to be in the range of 5–70%.<sup>28–31,44</sup> Children seem to be only mildly affected.<sup>45,46</sup> Overall patients with other illnesses such as diabetes and heart disease did poorly.<sup>44,47,48</sup>

There have been clusters of cases in the SARS epidemics, which have shown slightly different mortality figures, in particular, the Prince of Wales Hospital and the Amoy Gardens case clusters in Hong Kong, where different modes of transmission and clinical presentation syndromes were described.<sup>49,50</sup> It is difficult to make any definitive statement about these differences at present.

## Environmental survival

The survival of SARS CoV has been studied by various WHO laboratories<sup>51</sup> and the relevant figures have been summarized in Table 1. These have important implications for infection control in ward environments such as ICUs. However, as the virus may also survive on other inanimate objects or fomites, such as pens, patient notes, work surfaces, keyboards, telephones, etc., all HCWs need to be vigilant about the possibility of acquiring

**Table 1** Environmental survival data of SARS CoV, most relevant to ICU staff (adapted from the WHO tables.<sup>51</sup> All survival experiments used viral culture as means of detection. All data shown here obtained from the Chinese University of Hong Kong (CUHK).

Starting SARS CoV number	Conditions	Survival time (in buffered solution) <sup>a</sup> (in sterilized stool) <sup>a</sup>
90 000	On plastered wall	24 h 36 h
90 000	On plastic surface	36 h 72 h
90 000	Formica surface	36 h 36 h
90 000	Stainless steel	36 h 72 h
90 000	Wood	12 h 24 h
90 000	Cotton cloth	12 h 24 h
90 000	Pig skin	24 h 24 h
90 000	Glass slide	72 h 96 h
90 000	Paper file cover	24 h 36 h

<sup>a</sup>Implies that SARS CoV was first suspended in a buffered solution or added to sterilized stool before being laid onto these surfaces.

SARS from inadvertently touching such contaminated objects, then touching exposed mucous membranes, such as their eyes, nose and mouth where virus may enter and cause infection.

The SARS CoV is a lipid-enveloped virus, and as such should be inactivated by most commonly used disinfectants and fixatives, as well as by heating to 56°C.<sup>51</sup> Where organic material is present, the virus can survive much longer (see Table 1). The report on the Amoy Gardens outbreak of SARS demonstrated that SARS CoV could survive in faecal organic material, allowing it to have been transmitted by aerosol over some distance to cause many secondary infections.<sup>52</sup>

## Transmission risks and infection control

One of the ways of assessing the transmissibility of a pathogen is to estimate its basic reproductive number  $R_0$ . This is defined as the number of

secondary cases produced in a fully susceptible population, when a single infected case is introduced.<sup>53,54</sup> The effective reproductive number  $R$  is a measure of the transmissibility of a pathogen once it has become established in a population, some of which may be immune to infection.<sup>53,54</sup> For SARS CoV, the data suggest an  $R_0$  value of 2–4.<sup>55,56</sup> These estimates have deliberately omitted the so-called 'super-spreader' cases, which initiated the major epidemics in the severely affected countries. On this basis, SARS is not as infectious as measles, mumps, rubella, or influenza,<sup>57</sup> but it was the close proximity of HCWs to their patients, which gave rise to the high rate of HCW infections in the early part of the epidemic, before personal protective equipment (PPE) was widely used in hospitals.

Some of the routes of transmission of SARS CoV have been mentioned earlier, but it is generally accepted that direct contact or indirect contact of mucous membrane with SARS-infected body fluids, as well as short-range aerosol droplet transmission from a symptomatic, coughing patient, is sufficient to transmit SARS CoV.<sup>58</sup> Sometimes, secondary cases of SARS were due to iatrogenic causes, e.g. where SARS patients were treated with nebulizers or aerosol-assisted ventilation,<sup>28–31,33,34,59</sup> or during invasive procedures which created infectious aerosols, such as tracheostomy,<sup>30,34</sup> bronchoscopy,<sup>28,31</sup> cardiopulmonary resuscitation,<sup>60,61</sup> or endotracheal intubation.<sup>29,33,34,62</sup> In this context, the taking of respiratory samples for diagnosis such as nasopharyngeal aspirates (NPAs) would also constitute a significant risk to HCWs. So far, there is no evidence that there is transmission of SARS CoV before the onset of symptoms, which has contributed to the rapid control of the SARS epidemics.<sup>48</sup>

A study based on retrospective questionnaires of SARS-infected HCWs<sup>4</sup> suggested that the most important component of PPE was the facemask. Ideally, the mask should be fit-tested to check the effectiveness of the seal around the edge of the mask and the face, using kits that can be purchased for this purpose (e.g. the 3M 1873V FFP3 Health Care Respirator, 3M Health Care Ltd., Loughborough, UK). All staff dealing with suspect, probable or confirmed SARS patients, as defined by the WHO<sup>63</sup> (summarized in Table 2), should wear PPE consisting of at least: a mask of minimum N95 or P100/FFP3, or P99/FFP2 specification, a single pair of gloves, eye protection, a disposable gown, an apron and easily decontaminated footwear, as recommended by the WHO.<sup>64</sup> All staff should be trained to remove such PPE carefully without contaminating hands or clothes, with careful hand washing before, and after the use of such PPE. However, the effective use of PPE depends on

**Table 2** Definitions of SARS cases outside epidemic periods, relevant to ICU staff (adapted from the WHO websites).<sup>63</sup>

Suspect case	High fever (> 38°C) AND coughing or breathing difficulty AND EITHER close contact with a suspect/probable SARS case, OR a history of travel to an area with recent local SARS transmission, OR resides in an area with local SARS transmission
Probable case	A <i>suspect</i> case with EITHER radiographic evidence of infiltrates consistent with pneumonia or respiratory distress syndrome (RDS) on chest X-ray (or CT), OR is positive for SARS CoV by one or more laboratory assays (to be discussed with the testing laboratory, as this requires certain criteria to be met as defined by the WHO <sup>139</sup> )
Confirmed case	A <i>probable</i> case where there is no alternative diagnosis that can fully explain the illness

thorough staff training, diligence and motivation, and where this is lacking, breakthrough infections occur.<sup>65</sup>

As mentioned earlier, compared to other infectious pathogens that may be encountered on ICU, such as measles, chickenpox, influenza, tuberculosis, SARS CoV is not particularly transmissible. Unfortunately, the presence of the so-called 'super-spreaders', which may lead to multiple secondary cases, cannot be reliably determined in advance.<sup>54,66</sup>

During an epidemic, where SARS is known to be circulating in the community, patients with SARS-compatible symptoms, signs, travel or contact histories, who are admitted to hospital, should be treated as high risk for SARS. This is because the spectrum of SARS illness can range from mild to severe and may well not be present initially as a respiratory complaint. Also, there have been reports of afebrile cases of SARS occurring in the elderly (see below). This situation was encountered by Hong Kong, Singapore and Toronto, and consequently all HCWs working in the hospital building wore PPE of some kind, usually, at least a surgical-style mask. In Hong Kong, guidelines also graded the PPE to be used depending on the areas of highest risk for encountering/managing SARS patients, from simply a surgical mask in low-risk areas to full gown, cap, gloves, N95 mask and face visor for high-risk areas or procedures, managing patients with fever with or without respiratory symptoms.<sup>67</sup> Moreover, a single room with negative pressure was dedicated for aerosol-generating procedures such as taking nasopharyngeal aspirate, bronchoscopy and intubation, but the use of powered-air-purifying respirators (PAPR) was not routinely recommended. The Hong Kong Hospital Authority have also set a three-grade alert system (Green–Yellow–Red) dependent on whether active SARS cases are present in the local community or globally, and each grade has different implications for hospital infection control policy. In Singapore, in

addition, they used PAPR hoods for such high-risk procedures (personal communication, Tang Ong Teng, Singapore General Hospital; Leong Hoe Nam, Tan Tock Seng Hospital, Singapore). A study by Derrick and Gomersall<sup>68</sup> demonstrated that PAPR was also superior to standard surgical helmets that do not filter air through a high-efficiency particulate air (HEPA) filter. In Toronto, full body suits (Stryker T4) and PAPR were both available.<sup>61</sup> Ultimately, the cost vs. benefit of such equipment (particularly the PAPR hoods and suits) will have to be decided locally. Of course, the PPE available in each healthcare facility not only hospitals but also nursing/residential homes and general practice surgeries would depend on the perceived risk of encountering SARS patients. This in turn depends on whether SARS CoV is circulating in the local community or among returning travellers from endemic or epidemic areas with SARS-compatible symptoms.

Radiology is an important component of ICU care and, in SARS patients, the chest X-ray is particularly useful in monitoring response to treatment and disease resolution. However, there is also risk of transmission between patient and radiology staff as well as to the radiology equipment used in such imaging, which may allow SARS CoV to enter as well as leave the ICU with the radiology staff and equipment. This risk also needs to be considered in the day-to-day routine work on ICUs, and radiology staff need to be trained in how to use personal protective equipment appropriately.<sup>69,70</sup> The risk can be minimized by using dedicated equipment only, e.g. portable X-ray machines, for the high-risk areas.<sup>70</sup>

## Clinical features

The case definitions for suspected or probable SARS patients have been defined by the WHO,<sup>63</sup> and are

also summarized in Table 2. The clinical manifestations of SARS from various severely affected countries have already been well documented.<sup>5-7,71-75</sup> Briefly, the most common presenting symptoms in the first week are fever, cough, malaise, chills/rigours, myalgia and dyspnoea,<sup>48</sup> which cannot reliably be distinguished from other causes of respiratory infections, such as influenza, the common cold or other non-viral causes of atypical pneumonias. Occasionally, a patient who seems to have recovered in the first week of illness can suddenly deteriorate in the second week.<sup>76</sup>

The cough, if present, tends to be non-productive, and sore throat and rhinorrhoea are uncommon.<sup>48</sup> A minority of patients may exhibit diarrhoea, although in the Amoy Gardens cluster of patients, diarrhoea was a prominent presenting symptom, and the patients were more severely unwell, with a higher percentage of patients admitted to ICU, with a higher mortality.<sup>49</sup> Although initially reported as rare,<sup>77</sup> there are now several reports of mild<sup>78,79</sup> or asymptomatic<sup>80,81</sup> SARS cases. This may have implications for infection control, as such cases cannot be easily identified, and quarantined, although the infectivity of such SARS cases is not well established, presently. Also, atypical presentations of SARS may pose an infection control risk for similar reasons.<sup>82-84</sup>

SARS patients may also present to ICU because of complications of other diseases such as diabetes,<sup>83</sup> gastrointestinal bleeding,<sup>83</sup> leukaemia<sup>82</sup> and cardiac failure.<sup>84</sup> About 20–30% of SARS patients develop respiratory failure, requiring admission to ICU for mechanical ventilation.<sup>5,48,71,74,80,85,86</sup> The most common indication for ICU admission is respiratory failure, others were admitted due to multi-organ failure or other co-morbidity.<sup>5,43,74,80,86</sup> Intensive care staff need to be aware that such patients may also have SARS, and a careful contact history needs to be taken prior to admission.

Several authors have attempted to construct algorithms for diagnosing potential SARS patients based on the recognition of certain characteristic SARS clinical symptoms and signs.<sup>87-92</sup>

## Investigations

It is important to note that no single investigation is specific for SARS CoV infection. It is the overall picture that may be characteristic of SARS. Chest X-ray (CXR) changes, can be very variable and non-specific, sometimes appearing to be mismatched with the clinical symptoms and signs, and may or may not be present at the time of admission.<sup>78-81,83</sup> Several authors have reviewed the patterns of CXR

changes seen in cohorts of SARS patients,<sup>48,93,94</sup> but in most cases these patterns are probably too non-specific to be useful in individual cases. That the CXR changes with time seems to be characteristic in most cases<sup>94-97</sup> of SARS, and CXR and computed tomography (CT) changes correlate well with severe or late-stage SARS illness.<sup>98,99</sup> A symptomatic SARS patient, with a seemingly normal CXR, may go on to demonstrate an abnormal chest CT scan,<sup>100</sup> which then meets the current requirements for the WHO SARS case definition, outside the epidemic period (Table 2). This distinction was demonstrated in the recent SARS case from Singapore that involved a laboratory-acquired SARS CoV infection.<sup>101,102</sup>

Haematological and biochemical parameters in SARS patients have also been characterized,<sup>48,103</sup> the most consistent of which is an early lymphopaenia, sometimes with a thrombocytopaenia, and a neutropaenia or neutrophilia, with elevated alanine transferase (ALT) and aspartate transaminase (AST). Poor prognostic factors include: increasing age, initial high LDH, high absolute neutrophil count on presentation, male sex and hypoxia.<sup>5,48,71,72,74,104</sup> Zou et al.<sup>104</sup> used a multivariate model, to narrow this list down to just two parameters: low platelet count and degree of hypoxaemia, as the most significant prognostic factors.

## Virological diagnosis

SARS CoV has been detected in respiratory secretions, nasal and throat swabs, blood, urine and stool, by RT-PCR or virus culture (Tables 3a and b). SARS CoV can be grown from such specimens; this takes time and poses a significant risk to laboratory workers in handling live SARS CoV, which requires bio-containment level 3.<sup>105</sup> For diagnostic purposes, SARS CoV RNA can be detected by real-time or conventional RT-PCR from respiratory secretions,<sup>86,106-112</sup> but taking these samples exposes the HCW to possible respiratory transmission of SARS CoV and full PPE should be worn during such procedures. Viral genome can also be detected from stool samples<sup>107,110,112</sup> and also from blood samples taken during the first few days of the illness.<sup>113-115</sup> The level of virus in urine is too low for a reliable diagnosis. There are now commercial kits available for RT-PCR testing, which are becoming more sensitive and specific, and can give rapid results that will be clinically useful if they confirm the presence of SARS CoV, though false-positive results are possible, and a negative result cannot

**Table 3** (a) SARS CoV presence by RT-PCR and culture, in various clinical samples. Note that being detectable by RT-PCR, does not necessarily equate to *viable or live* virus. (b) SARS CoV presence by virus culture in various clinical samples, demonstrating *viable or live* virus.

Sample type	Week 1	Week 2	Weeks 3–4
	No. pos/no. tested (%)	No. pos/no. tested (%)	No. pos/no. tested (%)
<b>(a)</b>			
Tracheal aspirate	1/2 (50)	1/1 (100)	4/4 (100)
Stool	9/21 (42.9)	17/25 (68.0)	34/80 (42.5)
Pooled throat and nasal swabs	6/17 (35.3)	2/3 (66.7)	2/5 (40)
Nasal swab	9/27 (33.3)	5/14 (35.7)	1/17 (5.9)
Rectal swab	5/11 (45.5)	2/10 (20.0)	3/7 (42.9)
Throat swab	5/19 (26.3)	5/14 (35.7)	3/10 (30.0)
NPA	39/138 (28.3)	15/44 (34.1)	6/10 (60)
Throat washing	4/40 (10.0)	13/58 (22.4)	1/48 (2.1)
Urine	2/75 (2.7)	5/82 (6.1)	6/54 (11.1)
<b>(b)</b>			
Tracheal aspirate	2/3 (66.7)	1/1 (100)	0/3 (0)
Stool	2/24 (8.3)	0/28 (0)	0/141 (0)
Pooled throat and nasal swabs	4/18 (22.2)	0/3 (0)	0/1 (0)
Nasal swab	3/29 (10.3)	2/18 (11.1)	0/19 (0)
Rectal swab	0/14 (0)	0/12 (0)	0/35 (0)
Throat swab	2/23 (8.7)	0/15 (0)	1/15 (6.7)
NPA	23/171 (13.5)	6/54 (11.1)	0/9 (0)
Throat washing	0/36 (0)	1/62 (1.6)	0/51 (0)
Urine	0/110 (0)	0/86 (0)	2/76 (2.6)

Adapted from Chan et al.,<sup>112</sup> with permission. NPA = nasopharyngeal aspirate.

exclude a diagnosis of SARS. Other diagnostic tests include antibody tests (serology) for SARS CoV, which can be immunofluorescence format,<sup>12,13,116</sup> or enzyme-linked immunoassay (EIA) format.<sup>117,118</sup>

Most SARS patients had IgG antibody detected 2 weeks after the onset of illness. However, a confident exclusion of infection requires the testing of convalescent serum taken at more than 21 days after illness onset. Hence, the recommendations by the WHO SARS International Reference and Verification Laboratory Network to perform serology testing in the second and third weeks for SARS CoV antibody.<sup>119</sup>

It is important to consider the laboratory test results in the context of clinical symptoms and signs before classifying the patient as non-SARS, suspected, probably or confirmed SARS, as recommended by the WHO<sup>63</sup> (Table 2).

## Management

Several reviews have already been published on the detailed management of SARS patients on ICU.<sup>28–31</sup> However, the main focus of this review is on

limiting the transmission of SARS to ICU workers, rather than the day-to-day ICU management of SARS patients.

Various studies have published the results of intervention with single or a combination of agents, which have included various antibiotics, steroids, ribavirin, interferon,<sup>71–75,82,120–125</sup> convalescent sera<sup>126</sup> and protease inhibitors,<sup>127</sup> as well as some forms of Traditional Chinese Medicine (TCM).<sup>128</sup> None of these studies have demonstrated a consistent response to any of these therapies tried. Suffice it to say that there is no proven specific therapy for SARS patients, and the treatment is mainly supportive. The majority of cases (70–80%) do not need admission to ICU, though it is important to remember that individual cases may follow an unpredictable clinical course.<sup>76</sup> Therapeutic trials are urgently needed for this novel pathogen, but these may prove problematic due to lack of consensus on case definitions and a definitive diagnostic test, as well as difficulties identifying a study population and in defining clear outcomes.<sup>129</sup>

Transmission specifically involving ICU HCWs has already been reported.<sup>33</sup> Generally, by the time most patients present to ICU in severe respiratory

**Table 4** Recommendations on what ICU procedures should be avoided or only performed with highest level PPE on suspected, probable or confirmed SARS patients.<sup>28–31,33,34,60,140</sup>

Procedures to be avoided (where possible)	Procedures to be used
Nebulizers	Use simple face masks, nasal cannulae or non-rebreathing masks
Venturi-type masks	
Non-invasive ventilation	Close circuit suction
Open suction of airway	
Peak flow measurements	Scavenger system for exhalation port
High-frequency oscillation	
Other positive airway devices	Use two member approach if it is necessary
Normal saline instillation prior to suctioning	
Bronchoscopy	Put the fomites in plastic bag, fax the notes instead of transfer out of the ward
Manual bagging	
Moving of fomites from SARS to non-SARS areas	Negative air-pressure rooms
	Masks, gloves, waterproof gowns, cap, eye/face shields, disposable or easily decontaminated footwear/shoe cover
	Frequent cleaning of surfaces
	Hand washing and alcohol hand rubs
	High-efficiency particulate air (HEPA) bacterial/viral filters

Powered air purification respiratory (PAPR) hoods are strongly recommended for high risk, unavoidable procedures, e.g. endotracheal intubation, cardiopulmonary resuscitation, bronchoscopy, collection of nasopharyngeal aspirates, any procedure where ventilator tubing has the potential to be or is actually disconnected, e.g. manual lung recruitment, ventilator tubing changes, thoracentesis, tracheostomies, interventional radiological procedures.

distress, their SARS status will have already been decided: 'suspect', 'probable' or 'confirmed' SARS, and many may well have been in isolation. During a SARS epidemic, in those patients who present severe respiratory failure, requiring immediate admission to ICU, it is necessary to make a risk assessment based on the patient's travel history (if available) and the current epidemiology of SARS. There may be other accompanying complications in such patients, for example, there are reports of two pregnant women with SARS, one with tonic-clonic seizures, both of whom needed mechanical ventilation.<sup>130,131</sup>

If the past experience of March to July 2003 is to be repeated in the UK, it will be very difficult to ascertain at the point of admission, whether severe respiratory failure will necessarily be due to SARS or even to another emerging respiratory pathogen, such as the human cases of the currently ongoing H5N1 avian influenza epidemic in Southeast Asia, with human fatalities in Thailand and Vietnam.<sup>132</sup>

Whereas in the SARS epidemic areas during early 2003, such as Hong Kong, Singapore and Toronto, all HCWs started wearing PPE as soon as they entered

their hospitals, in the UK, since very few cases of genuine SARS were seen by HCWs, the wearing of PPE was not automatic in hospitals. Unfortunately, in the UK, it is therefore likely that clusters of SARS CoV-infected HCWs, may well be the first sign that a genuine SARS case has been admitted. Such clusters of infected HCWs were described in the early stages of the SARS epidemics elsewhere, in March 2003, when SARS was just beginning to be recognized.<sup>133–135</sup>

The WHO criteria for a confirmed SARS patient may not be met for sometime, as radiographic changes may take time to appear, as in the recent lab-acquired SARS case from Singapore.<sup>101,102</sup> Therefore, ICU workers will more often encounter suspect or probable SARS, in which case the infection control procedures from many sources, well documented now, should be followed. Recommended procedures to be avoided or performed on ICUs are given in Table 4, and infection control guidelines from Prince of Wales Hospital ICU, Hong Kong, are shown in Box 1. Other invasive procedures (e.g. insertion of central venous pressure lines, arterial lines), patient sampling (e.g.

**Box 1**

An example of infection control guidelines, modified and adapted, from the Prince of Wales Hospital ICU, Hong Kong.<sup>[140]</sup>

**Staff education**

1. Instructions on dressing and undressing of PPE without contamination.
2. Importance of vigilance and adherence to all infection control procedures.
3. Training on performing high-risk procedures, to avoid the need for less skilled staff to perform such procedures on high-risk patients.
4. Importance of monitoring and reporting of own health.

**Dress and behavioural precautions**

1. Airborne precautions using N95 masks/respirators.
2. Contact precautions.
3. Eye protection.
4. Hand cleaning:
  - i. After all patient contact.
  - ii. After removing gloves.
  - iii. On entry and before leaving ICU.
  - iv. Before using keyboards, telephones, etc.
  - v. If hands are visibly soiled, hand washing is required. If not, alcohol-based disinfectant rubs may be superior for viral disinfection.
5. Do not touch nose or eyes at work.
6. Plastic covers for pagers, pens and other inanimate objects.
7. No visitors or restriction on numbers of visitors.
8. Care with disposal of excreta to avoid splashes.
9. No eating or drinking in the ward.
10. Staff entering and leaving high-risk areas should be segregated.
11. Staff coming into direct contact with patients' body fluids should immediately take a shower.
12. Spontaneously breathing patients should wear a surgical mask.

**On entering the ICU**

1. Clean hands by washing or rubbing with alcohol-based disinfectant
2. Put on the PPE in the following order:
  - i. N95 mask—check the mask for air leak.
  - ii. Full face visor.
  - iii. Cap.
  - iv. Waterproof gown.
  - v. Shoe cover.
3. Clean hands again by washing or rubbing with alcohol-based disinfectant.
4. Put on gloves.
5. Look in mirror to check the PPE has been put on properly.

**On leaving the ICU**

1. Remove PPE in the following order:
  - i. Cap.
  - ii. Gown.
  - iii. Shoe covers.
  - iv. Gloves.
2. Wash hands or rub with alcohol-based disinfectant.
3. Remove face visor and mask.
4. Wash hands or rub with alcohol-based disinfectant.
5. Put on surgical mask.
6. Wash hands or rub with alcohol-based disinfectant.

**Environment modification**

1. Negative pressure isolation rooms with antechambers and doors closed at all times.
2. Easily accessible hand-washing basins.
3. Easily accessible and adequate supply of PPE and alcohol-based hand wash.
4. Careful and frequent cleaning of environmental surfaces with alcohol-based detergents.

**Box 1** (continued)

5. Disposable keyboard covers.

**Ventilation and intubation**

1. Avoid use of nebulizers, ventri-type masks and heated water humidifiers.
2. Avoid non-invasive ventilation through BiPAP ventilator.
3. Avoid ventri-type masks, use simple face masks, nasal cannulae or non-rebreathing masks.
4. Avoid open suctioning of airway secretions.
5. Avoid peak flow measurements.
6. Only allow experienced doctors to attempt intubation.
7. Muscle relaxants should be used to facilitate intubation and minimize the risk of the patient coughing.
8. Use a nerve stimulator before changing endotracheal tube to ensure the patient is adequately paralyzed before attempting laryngoscopy.
9. Prepare all drugs and equipment in advance.
10. Use close-circuit suction.
11. Use HEPA bacterial/viral filters.
12. Use scavenger system for exhalation port.
13. Minimize manual bagging, two members approach should be used if it is essential: one holds mask tightly against patient's face while the other squeezes bag gently.
14. Inflate endotracheal tube (ETT) cuff before ventilating the patient.
15. Ensure cuff of ETT is adequately inflated.
16. Staff involved in the intubation should remove PPE and don new PPE immediately after the intubation procedure.

**Transport of patients**

1. Minimize the transport of patients where possible.
2. Use dedicated lifts for transport of patients.
3. Alert infection control unit before transportation.

blood, stool, respiratory secretions, urine) should be performed wearing full PPE, as already described above.

## Conclusions

The main message here is to consider SARS in the differential diagnosis of certain patients with a compatible clinical presentation and a history, which may have a possible SARS CoV contact, component. The next step is to act accordingly with regard to infection control precautions, although the assessment of risk of transmission is often difficult to make. If a SARS case goes unrecognized, then case clusters will start to appear,<sup>136</sup> however, with good infection control, both hospital and community cases of SARS can eventually be brought under control.<sup>137,138</sup>

It is important to note that the guidelines offered here have been based on the most recent experience, mainly from the SARS epidemic of early 2003. The SARS CoV, as a new pathogen adapting to a new host, may possibly alter its clinical presentation and transmissibility in the future. Recently, long

range aerosol transmission of SARS CoV was demonstrated to be a likely explanation for the SARS outbreak at Amoy Gardens estate in Hong Kong.<sup>141,142</sup> This event, therefore raises some difficult problems for infection control, both in healthcare institutions and in the community.

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